Progress in HIRFL-CSR

Guoqing Xiao for CSR team

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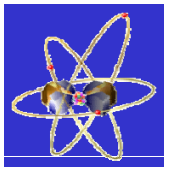
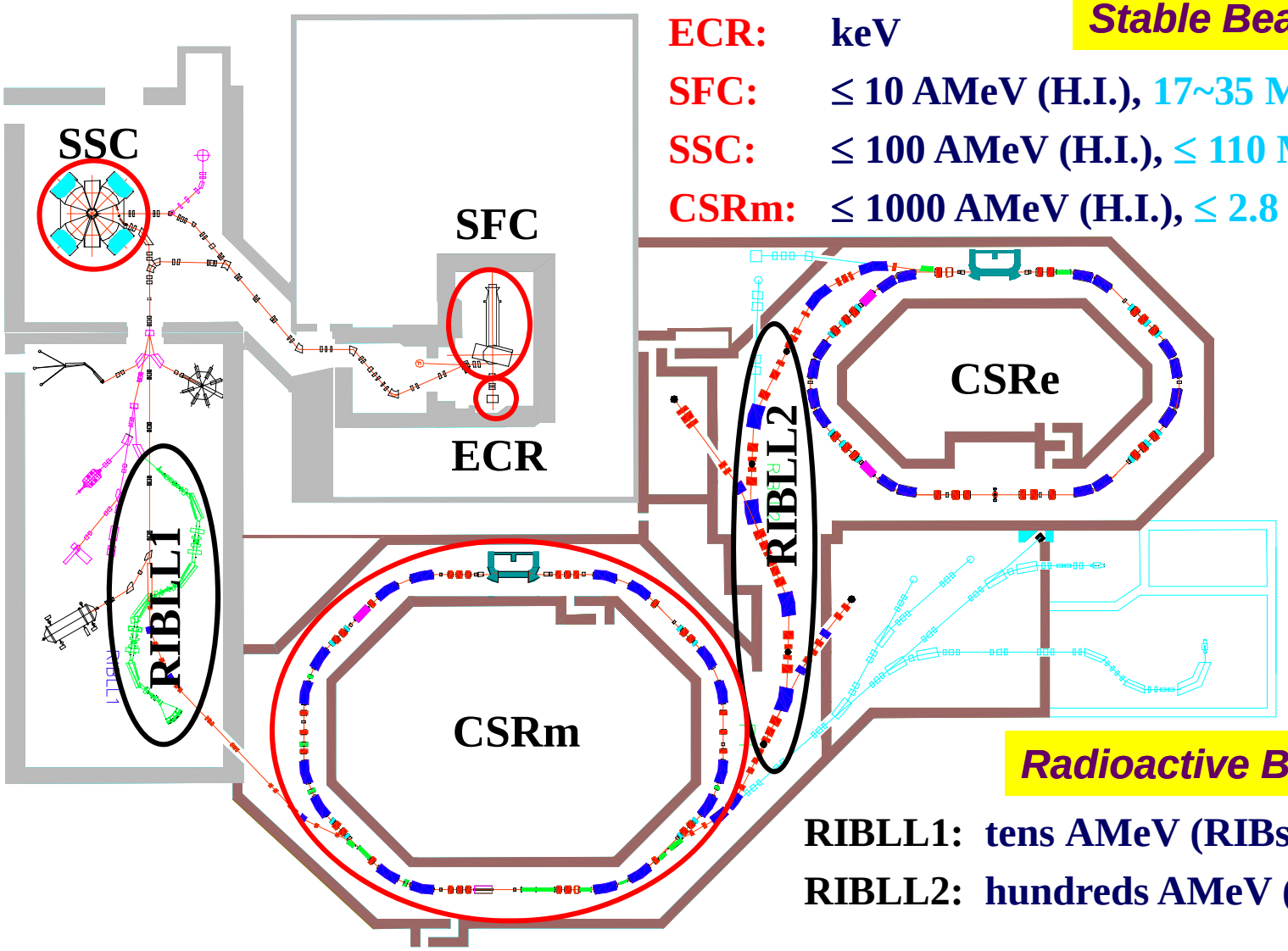


Institute of Modern Physics (IMP), Chinese Academy of Science (CAS)
National Laboratory of Heavy Ion Accelerator in Lanzhou

Introduction to HIRFL

HIRFL: Heavy Ion Research Facilities in Lanzhou



Stable Beams

ECR: keV

SFC: ≤ 10 AMeV (H.I.), 17~35 MeV (p)

SSC: ≤ 100 AMeV (H.I.), ≤ 110 MeV (p)

CSRm: ≤ 1000 AMeV (H.I.), ≤ 2.8 GeV (p)

N

Radioactive Beams

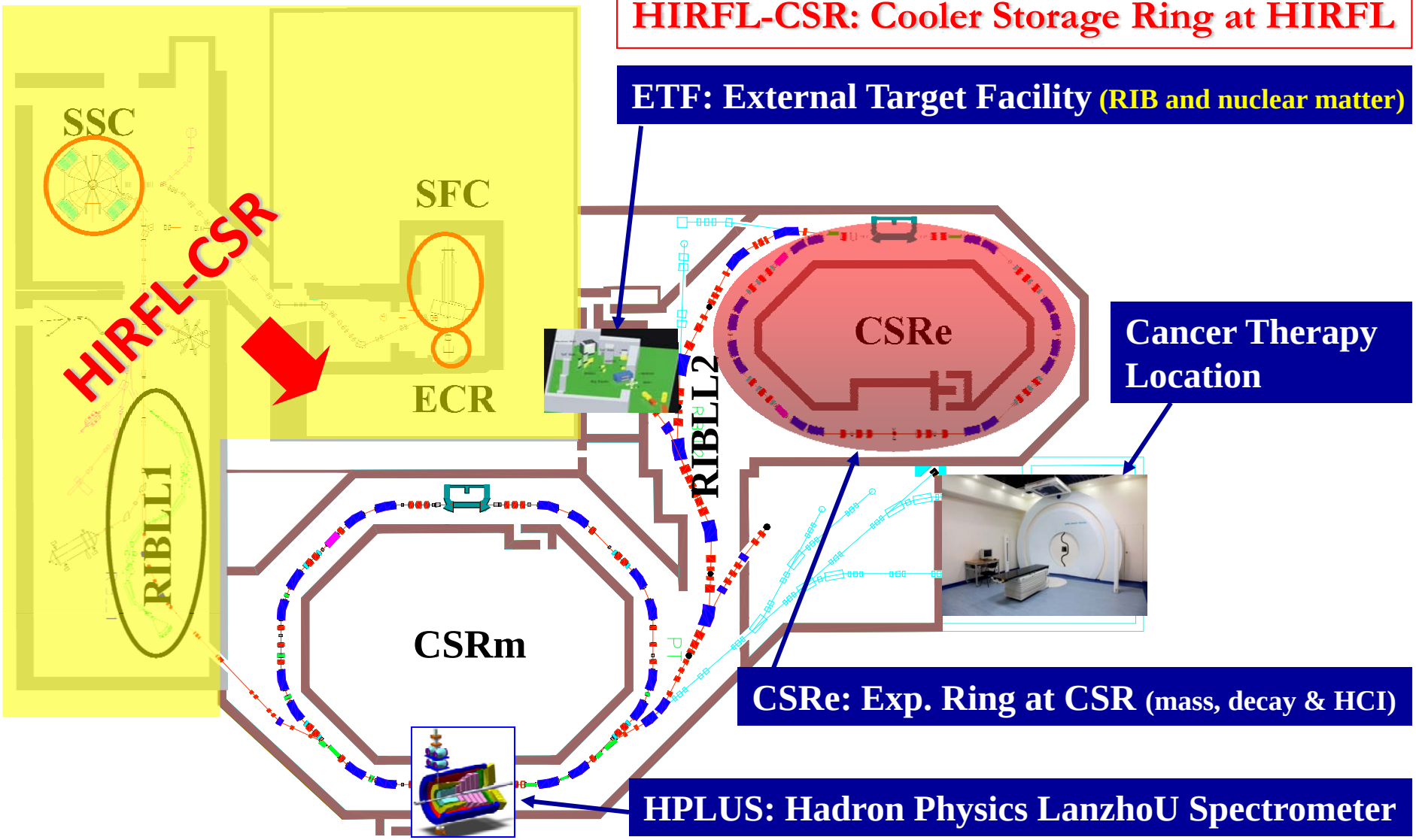
RIBLL1: tens AMeV (RIBs)

RIBLL2: hundreds AMeV (RIBs & HCI)

What is HIRFL-CSR

HIRFL-CSR: Cooler Storage Ring at HIRFL

ETF: External Target Facility (RIB and nuclear matter)

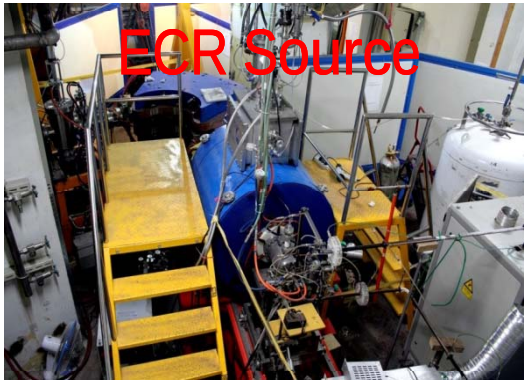


Cancer Therapy Location

CSRe: Exp. Ring at CSR (mass, decay & HCI)

HPLUS: Hadron Physics LanzhoU Spectrometer

Injection Mode of CSR



A< 40

CSRm

A≥ 40

- ***Stripping* Injection*:***

  A<40

- ***Multiple Multi-turn Injection:***

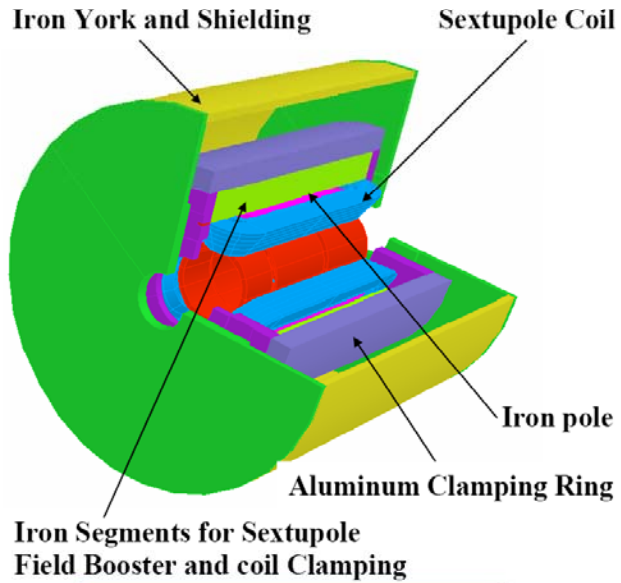
  A≥ 40

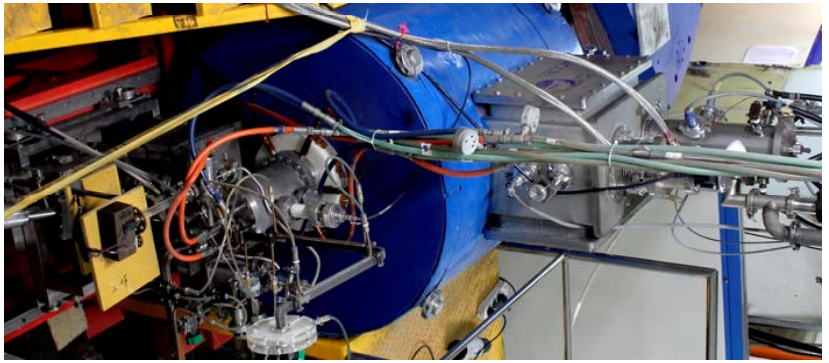
SECRAL: Superconducting ECR-source At Lanzhou

Ions	Q	SECRAL 18 GHz (μA)	VENUS 28 GHz (μA)
^{16}O	6+	2300	2860
	7+	810	850
^{40}Ar	16+	73	270
	17+	8.5	36
^{129}Xe	20+	505	320
	27+	306	270
	28+	260	222
	34+	21	40
	39+	5	
	42+	1.5	0.5
	43+	1	
^{209}Bi	41+	22	15
	44+	15	7.7
	46+	10	3.6
	48+	4.2	1.4
	50+	1.5	0.5

SECRAL is being tested at 24+18GHz.

- **SECRAL operated from 2008 and delivered Xe^{27+}, Kr^{19+}, Bi^{31+}, Ni^{19+} for >2000 hrs**





SFC: Sector Focusing Cyclotron

- **Built in 1960s;1st modification in 1970s; 2nd modification around 2000**
- **K=69, R ~0.75 m**

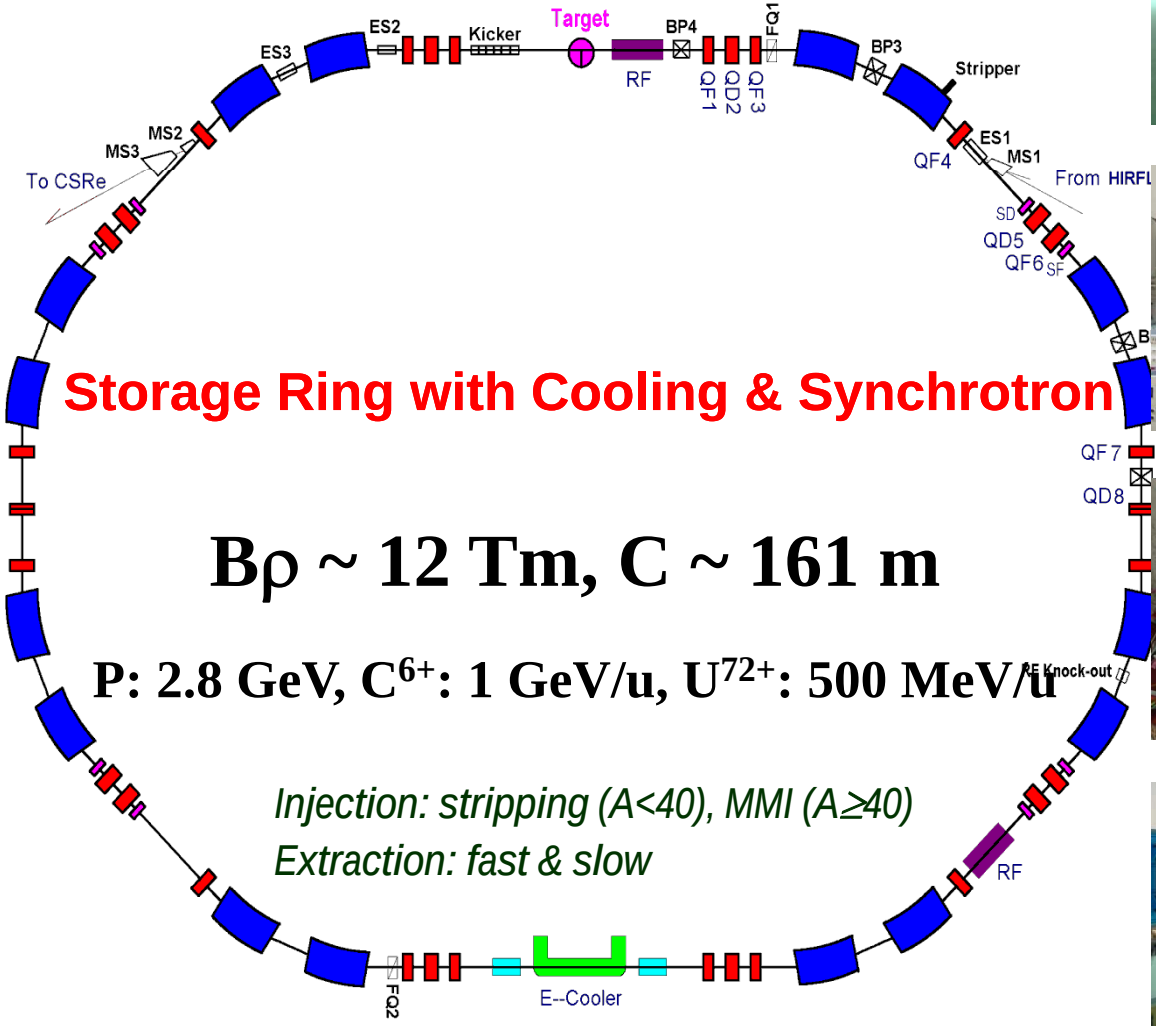
SSC: Separated Sector Cyclotron

- Built in 1980s
- K=450, R ~3.203 m

C: ~100MeV/u
U: ~10 MeV/u

CSRm: Main Ring of CSR System

Installed in June,2004



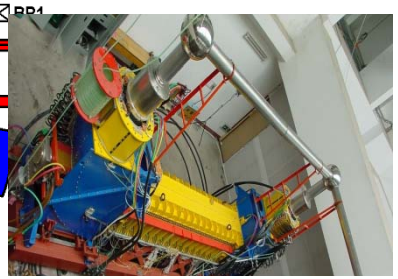
Storage Ring with Cooling & Synchrotron

Bρ ~ 12 Tm, C ~ 161 m

P: 2.8 GeV, C^{6+}: 1 GeV/u, U^{72+}: 500 MeV/u

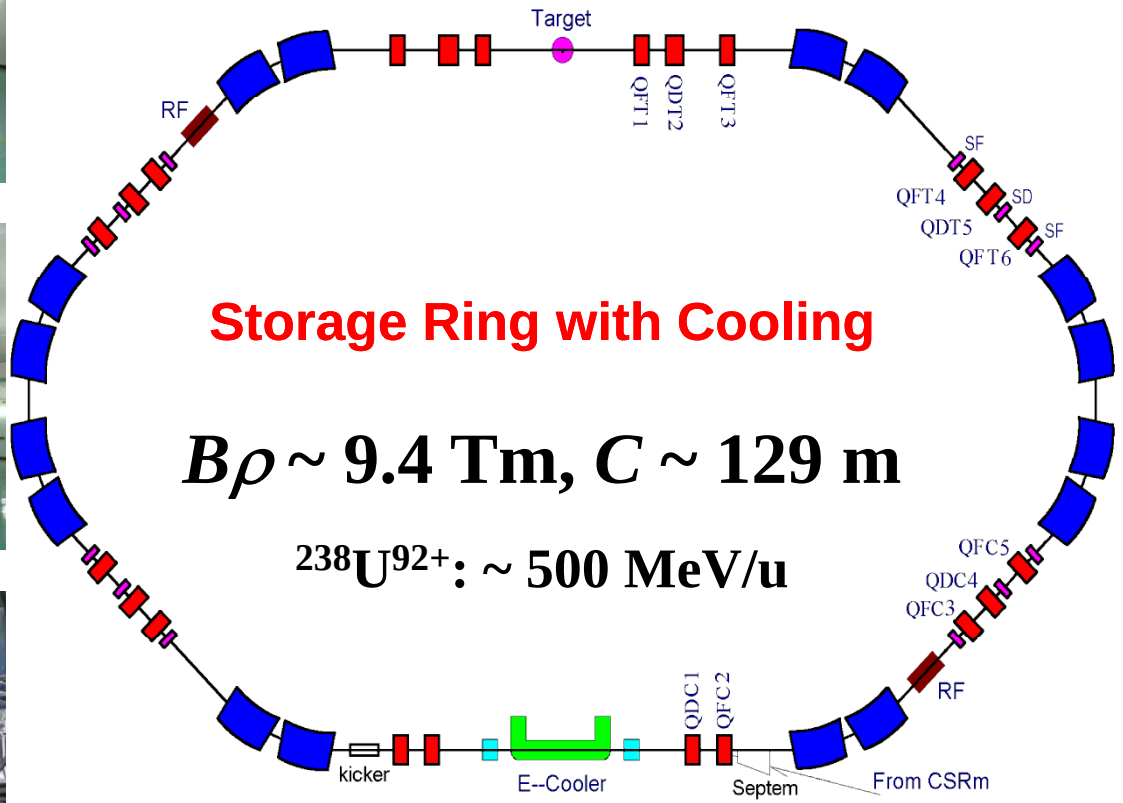
Injection: stripping (A<40), MMI (A≥40)

Extraction: fast & slow



CSRe: Experimental Ring of CSR System

Installed in October,2005



Storage Ring with Cooling

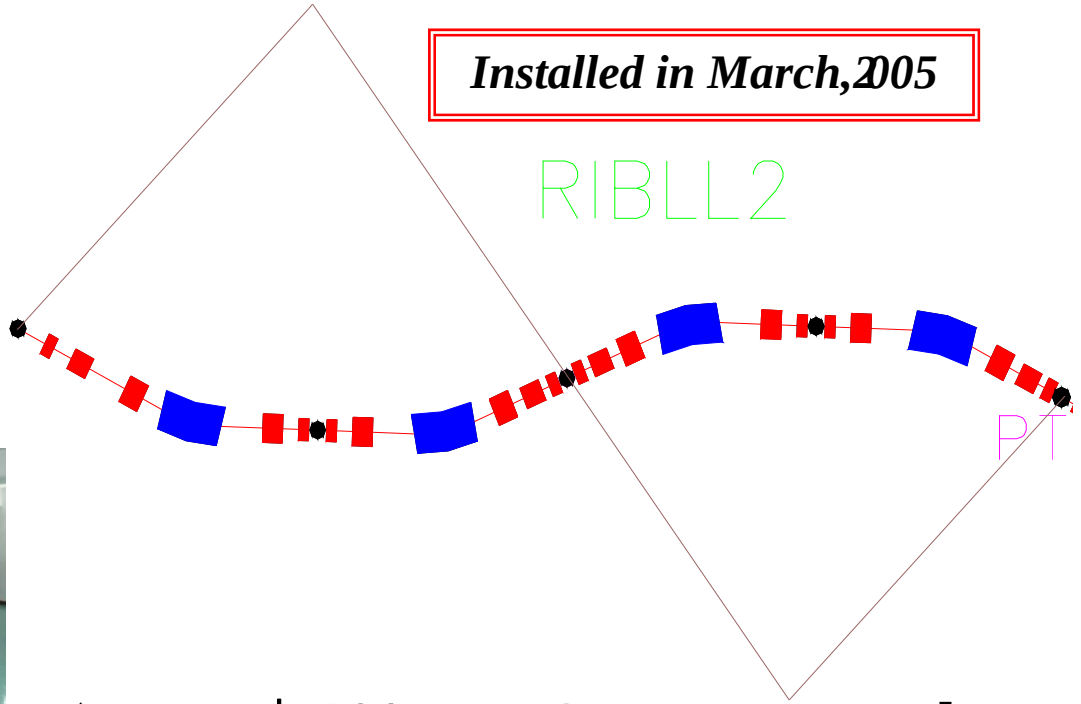
$B\rho \sim 9.4$ Tm, $C \sim 129$ m

$^{238}U^{92+}$: ~ 500 MeV/u

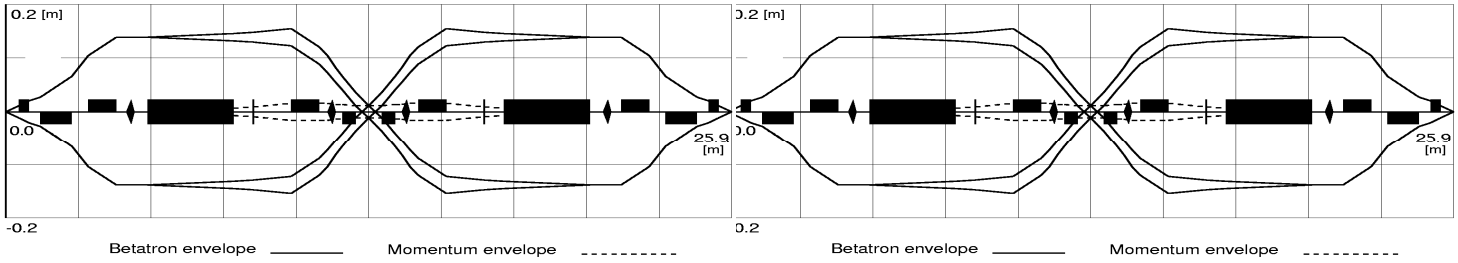
RIBLL2: 2nd Radioactive Ion Beam Line in Laznhou

- Beam transport line between CSRm and CSRe
- Producing RIBs and HCI

Installed in March,2005



$\Delta P/P = \pm 1\%$, $\varepsilon = 25\ \pi$ mm·mrad



History of CSR

1993	Original idea
1996	Proposal
1998	Approved
2000-2005	Construction
2006-2007	*Commissioning*
2008-2009	Operation & Experiments

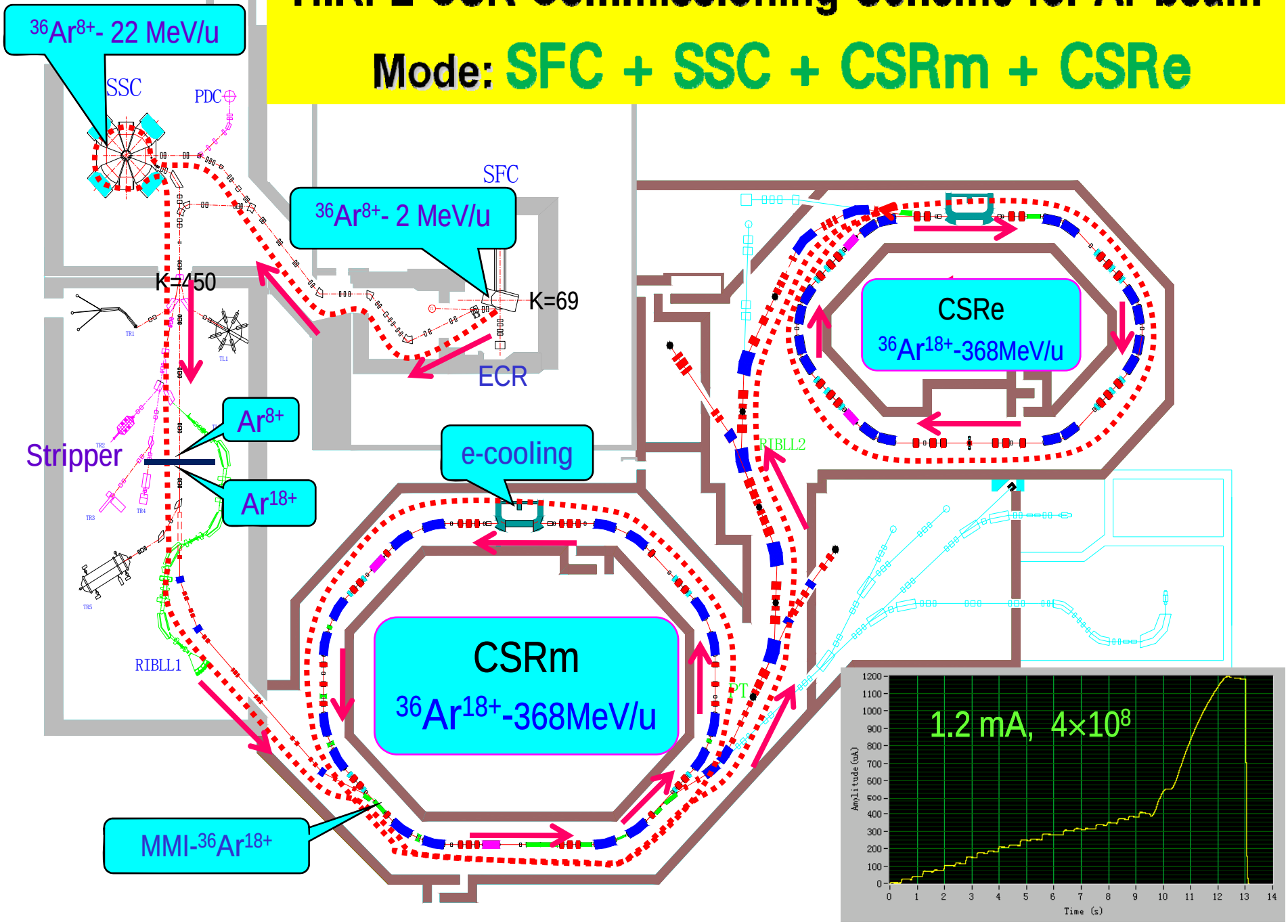
CSR Commissioning

Milestones

- **1st stored beam at CSRm ($^{12}C^{6+}$)** **Jan. 23, 2006**
- **$^{12}C^{6+}$ ramping: 7 MeV/u- 1 GeV/u** **Oct. 24, 2006**
- **1st cooling beam** **Dec. 27, 2006**
- **1st Multiple Multi-turn Injection ($^{36}Ar^{8+}$)** **Apr. 24, 2007**
- **Fast extraction (600 MeV/u $^{12}C^{6+}$)** **Aug. 04, 2007**
- **1st stored beam at CSRe (600 MeV/u $^{12}C^{6+}$)** **Oct. 06, 2007**
- **RIB stored in CSRe & running CSRe as IMS** **Dec., 2007**
- **Slow extraction** **Jan. 10, 2008**

HIRFL-CSR Commissioning Scheme for Ar-beam

Mode: SFC + SSC + CSRm + CSRe



Present CSR Beam Status

Ion: $^{12}C^{6+}$, $^{36}Ar^{18+}$, $^{78}Kr^{28+}$, $^{129}Xe^{27+}$

Energy: 1GeV/u for C & Ar in CSRm

Intensity: 10mA (7×10^9) for C-600 MeV/u in CSRm
1.2mA (4×10^8) for Ar-368 MeV/u in CSRm
0.6mA (1×10^8) for Kr-480 MeV/u in CSRm
0.5mA (1×10^8) for Xe-235 MeV/u in CSRm
15mA (8×10^9) for C-660 MeV/u in CSRe

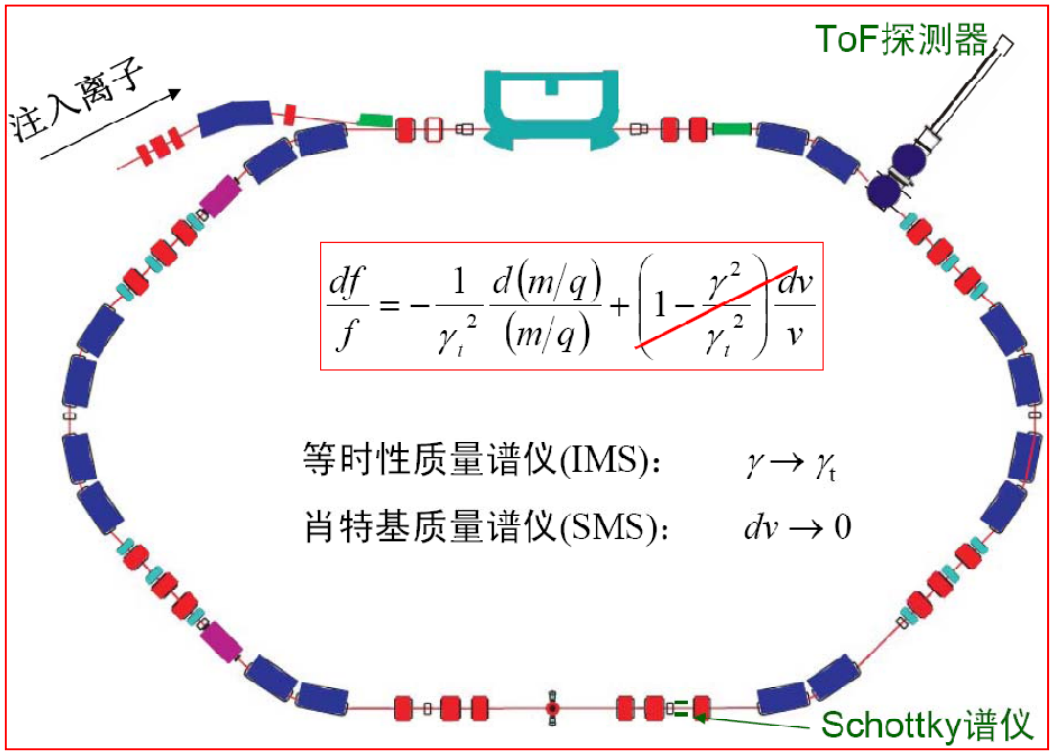
Experiment: RIBs mass-measurement, isochronous mode of CSRe , $\Delta M/M\sim10^{-6}$

Slow-extraction: For detector testing at external-target experiment location and cancer therapy

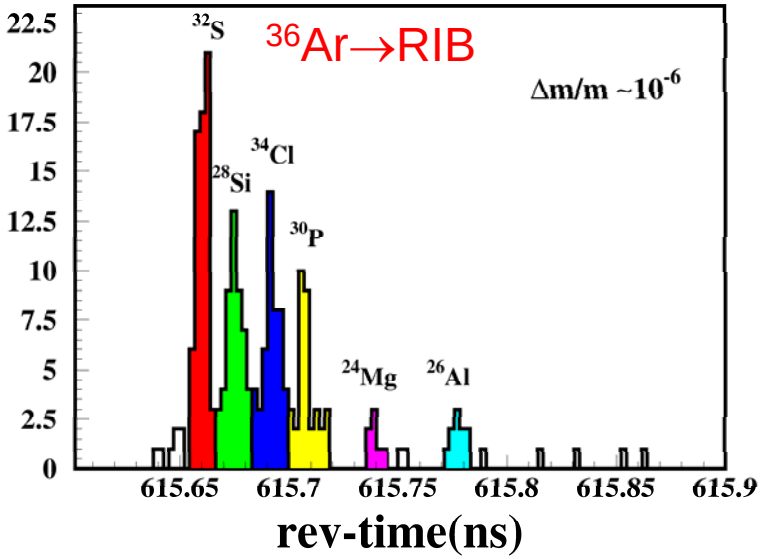
HIRFL-CSR Control Room

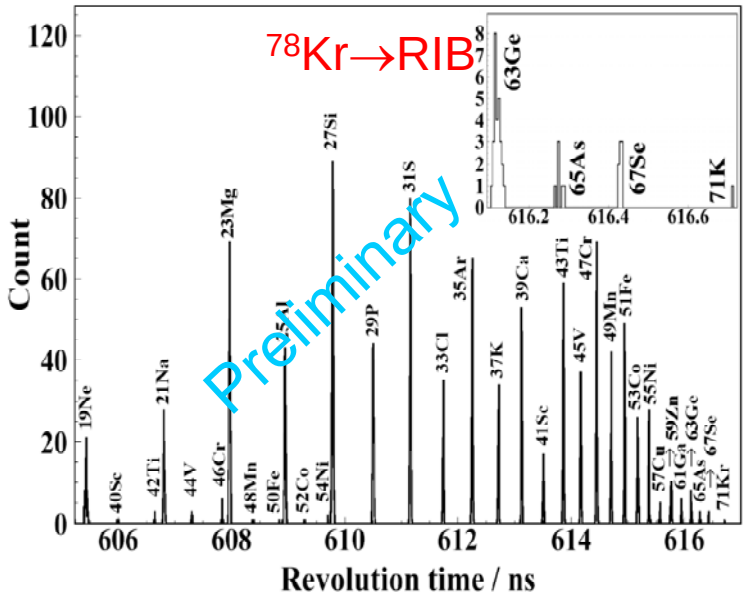
RIBLL2＋CSRe

Isochronous mass spectrometer



- Dec. 2007: ^{36}Ar test run
- Jan. 2009: ^{78}Kr test run





^{78}Kr Run

CSRm

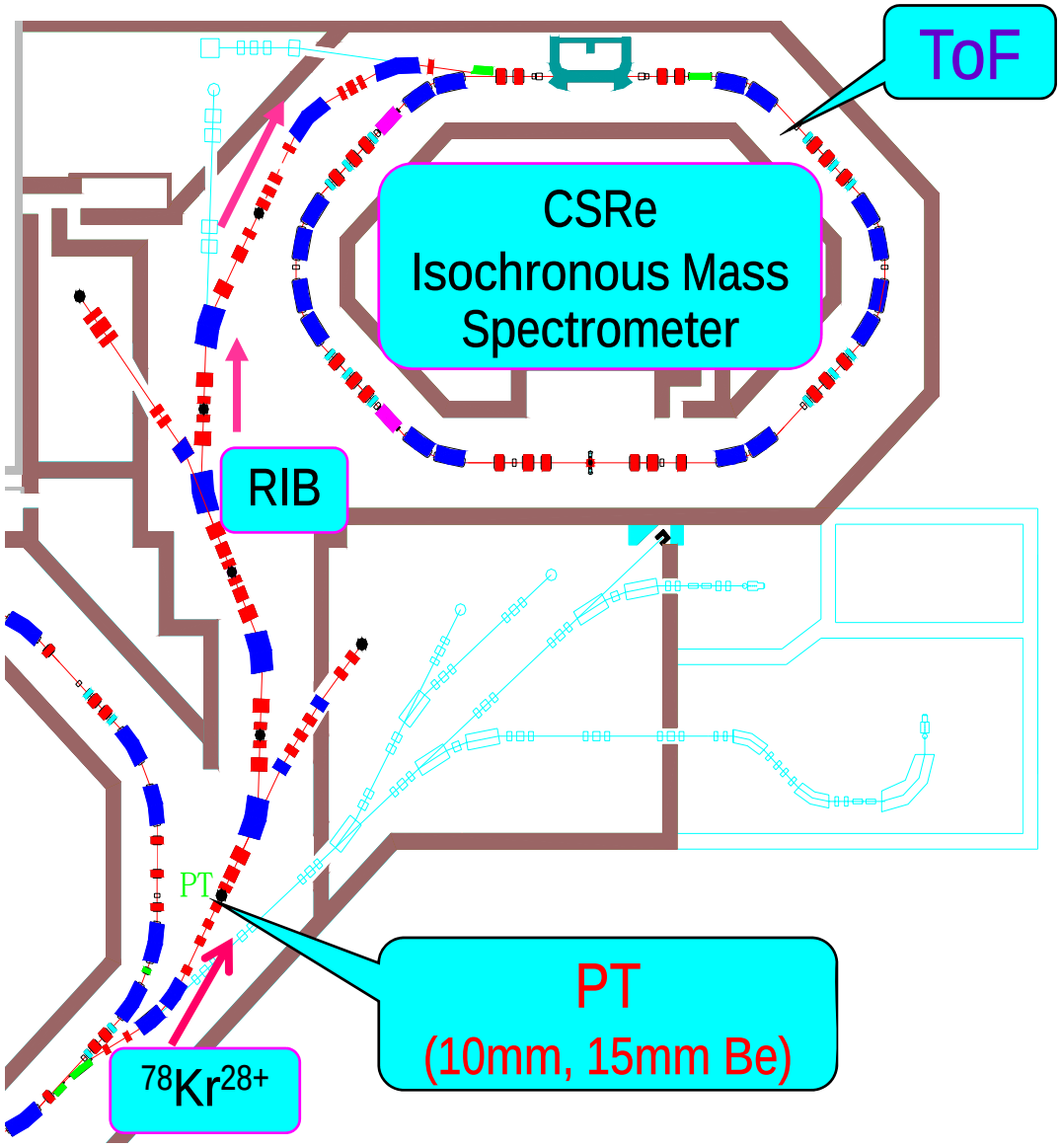
$^{78}Kr^{28+}$

447.8MeV/u

451.1MeV/u

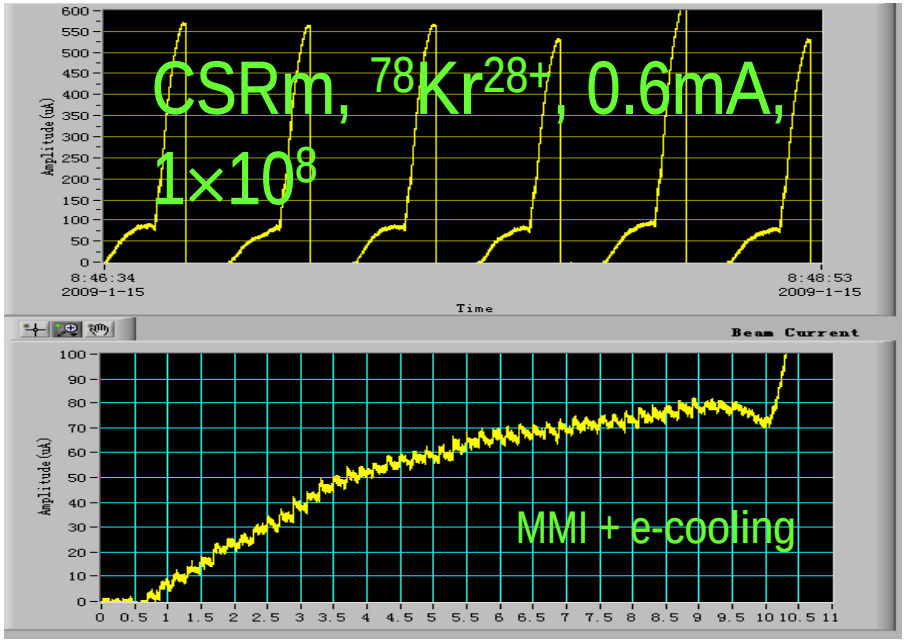
458.4MeV/u

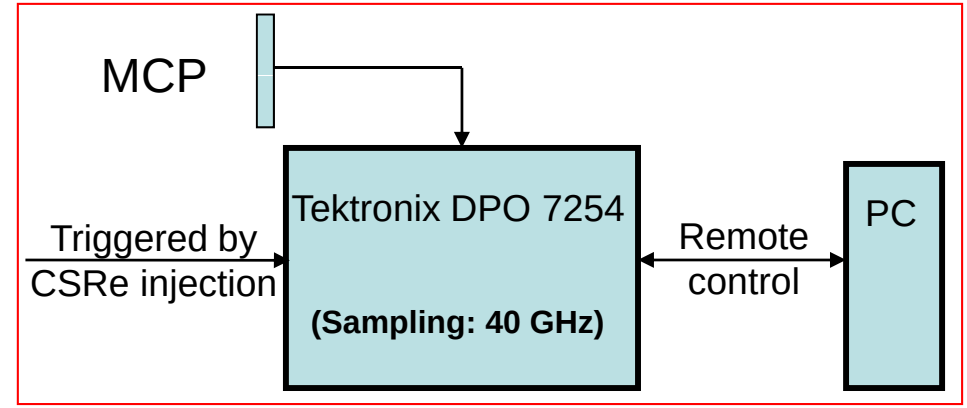
481.9MeV/u



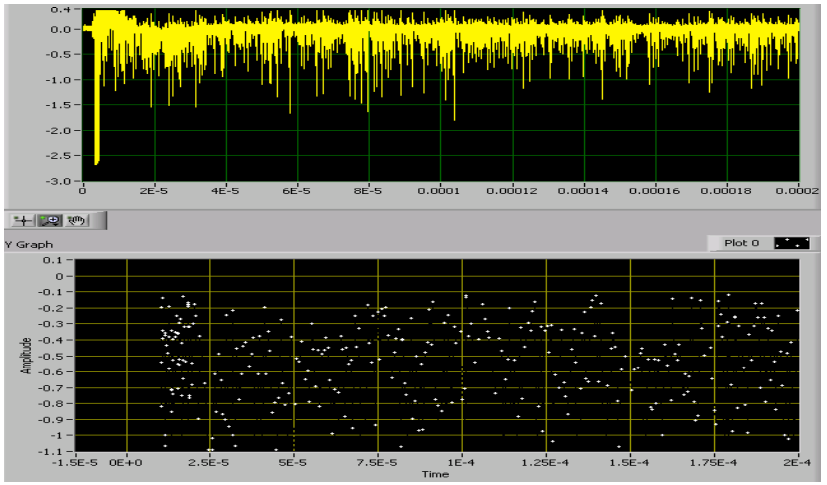
^{78}Kr Run

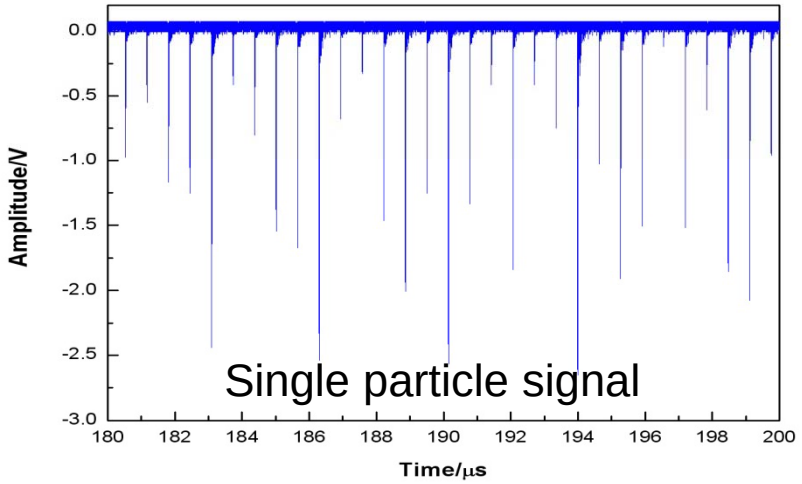
Primary beam in CSRm



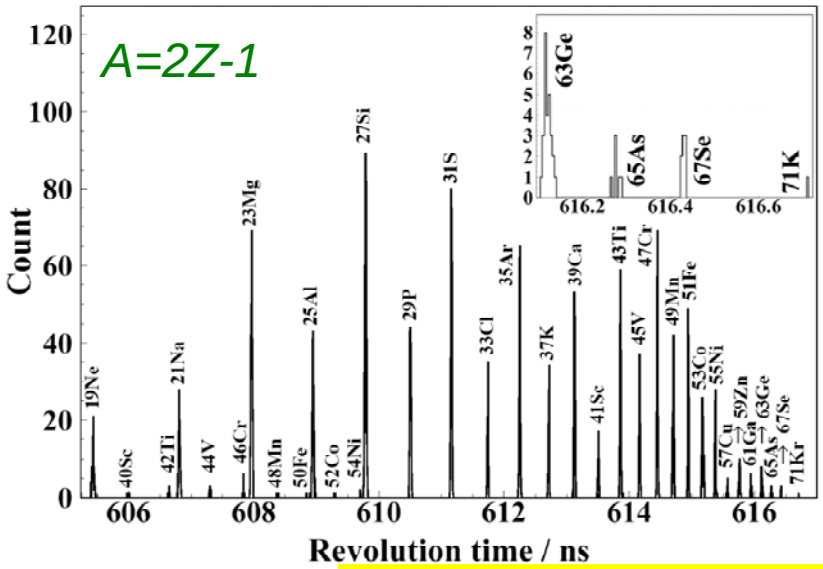


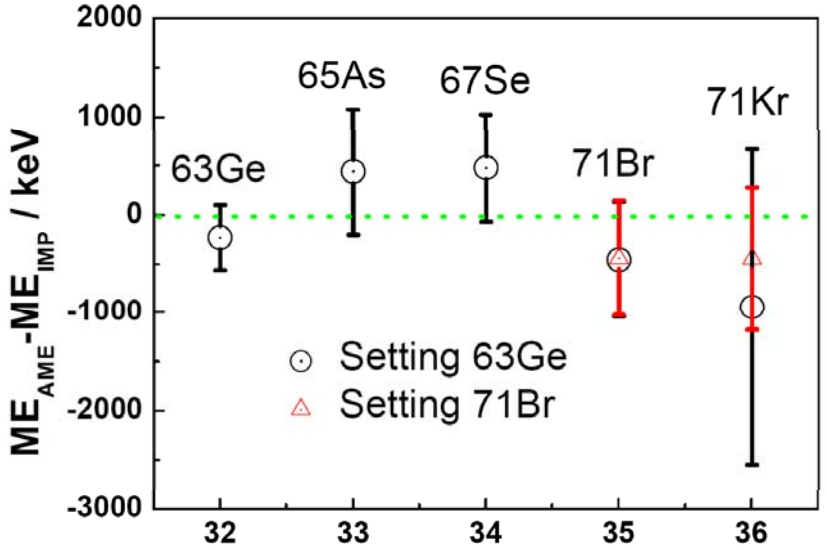
Signal from ToF detector in CSRe



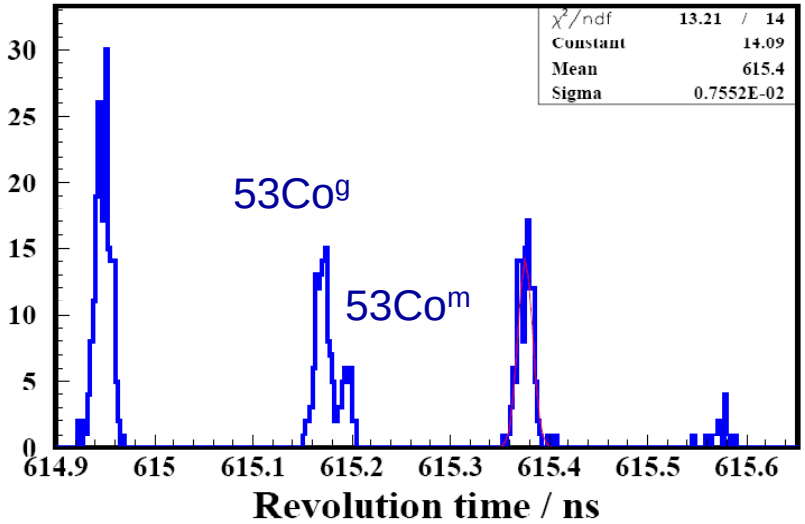


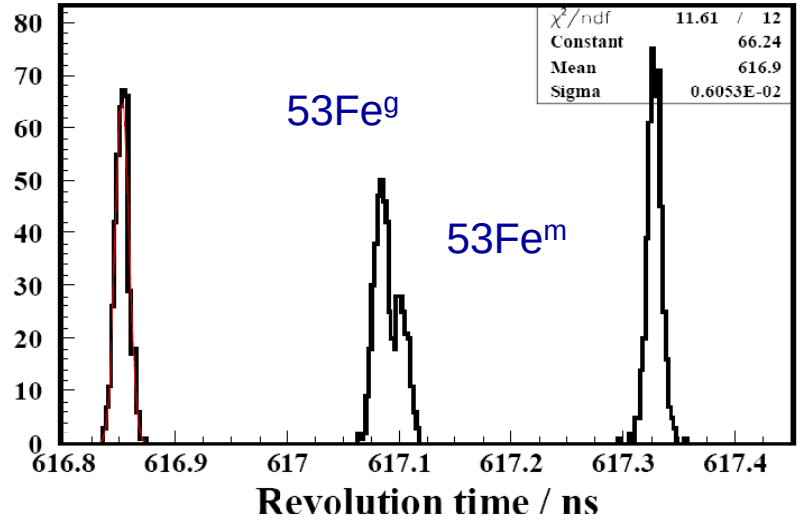
Preliminary Results of ^{78}Kr Run





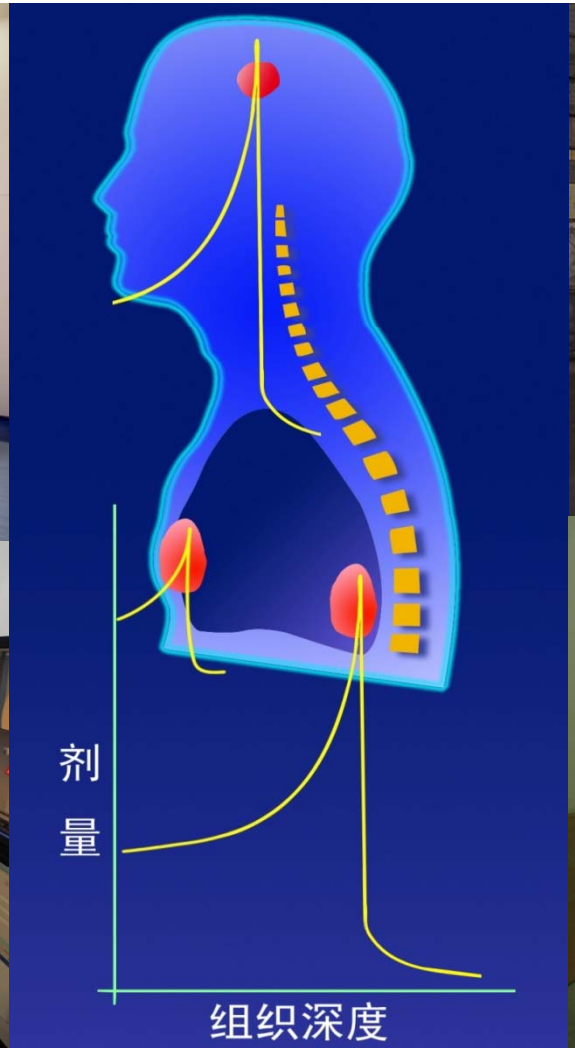
3 new mass data: ^{63}Ge, ^{65}As and ^{67}Se



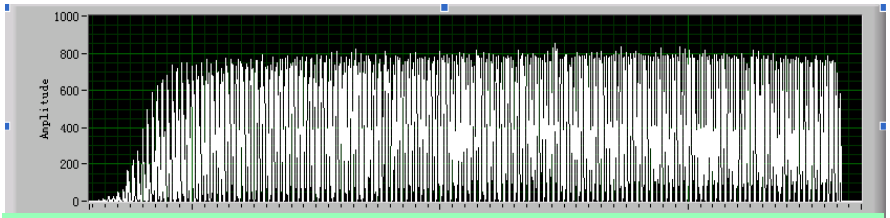


Cancer Therapy

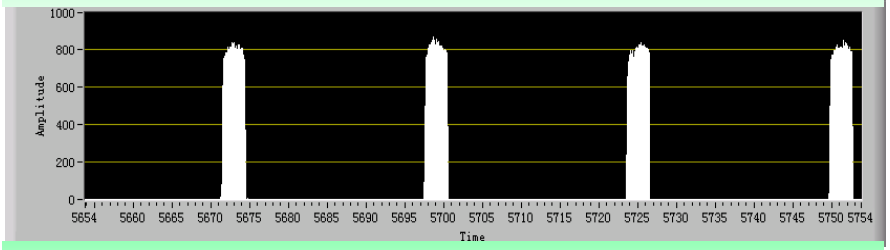
- 03-04, 2009: 6 patients
- 07, 2009: 2 patients

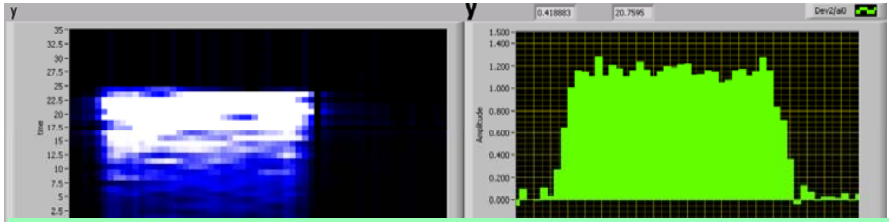


Beam Quality for Cancer Therapy

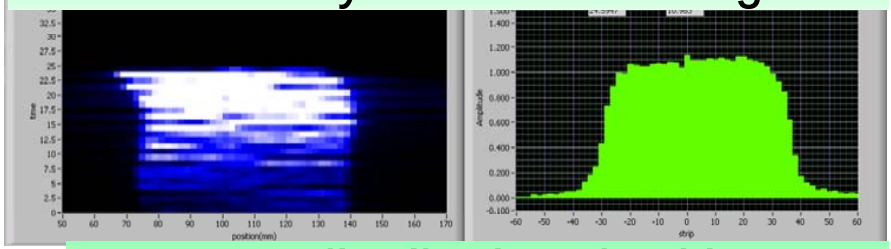


Slow extraction for C-beam in 3s

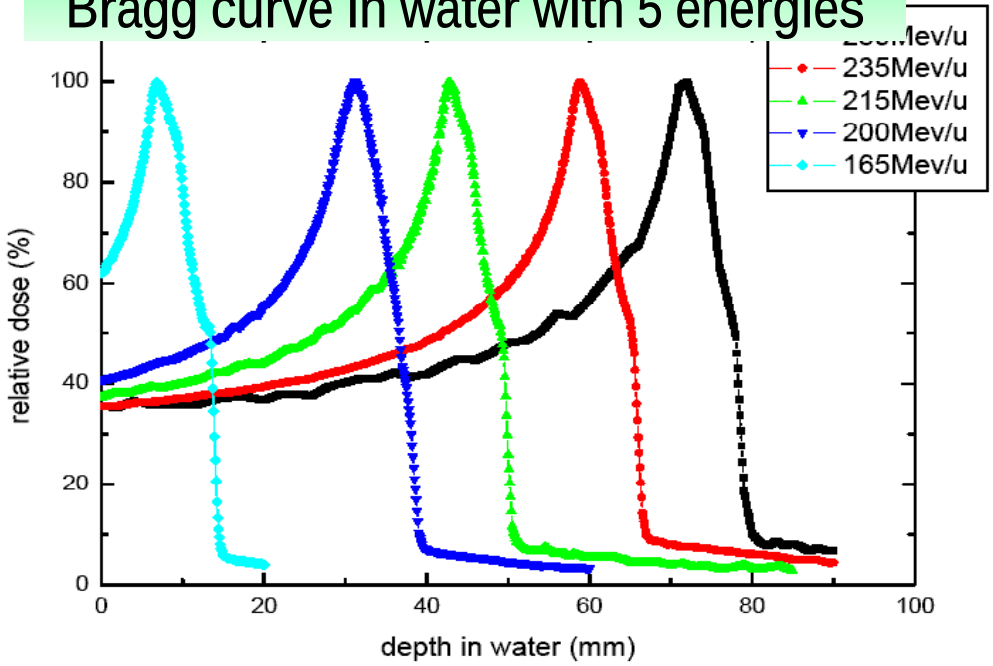




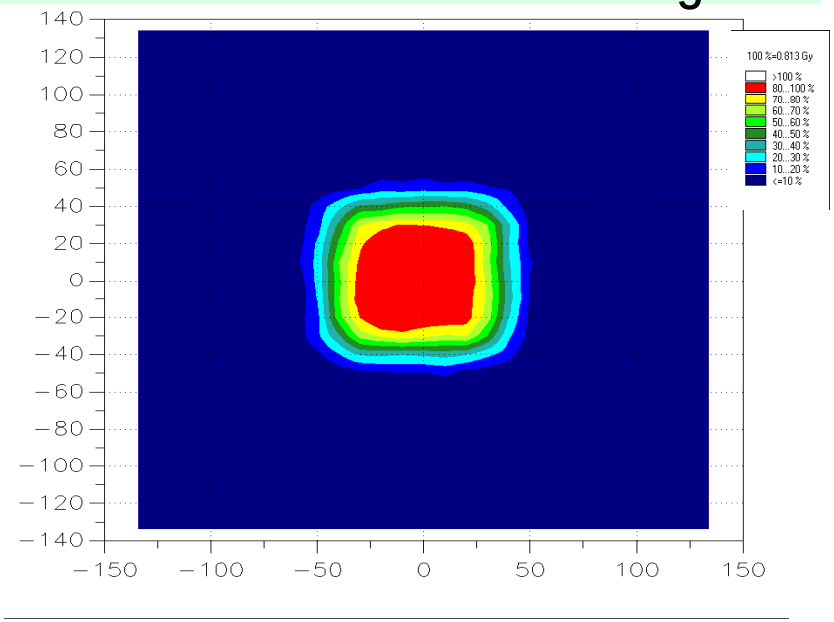
Uniformity online monitoring



Bragg curve in water with 5 energies



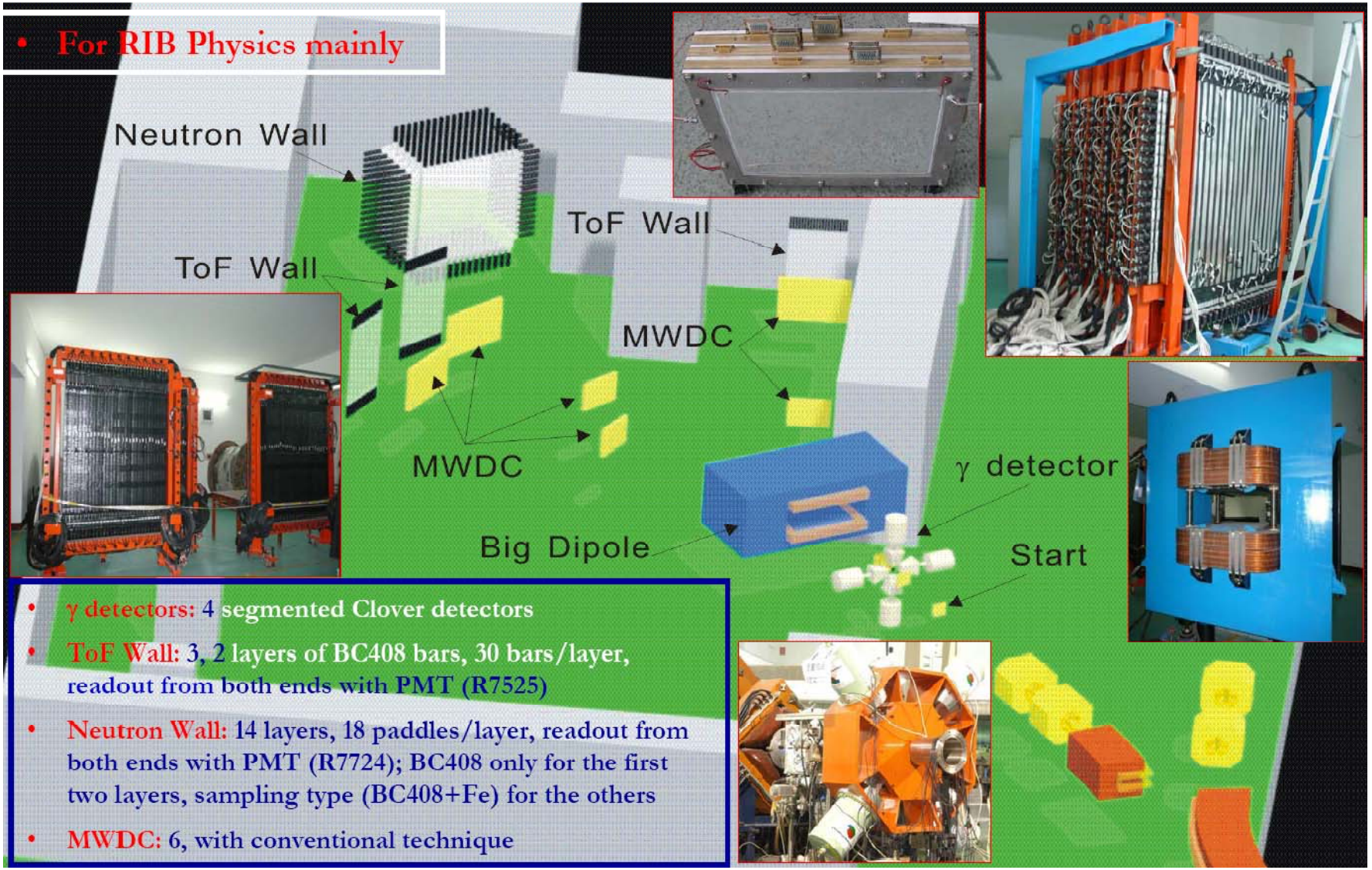
Dose distribution checking



ETF: External Target Facility

Phase I

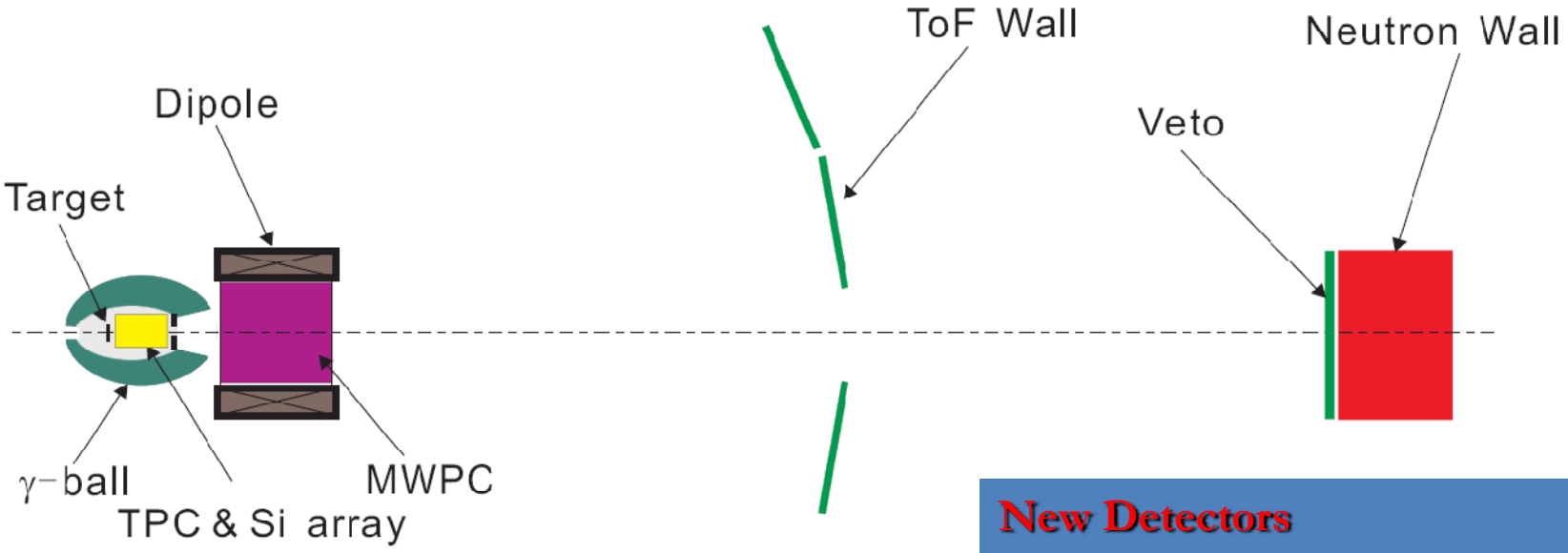
Nearly ready

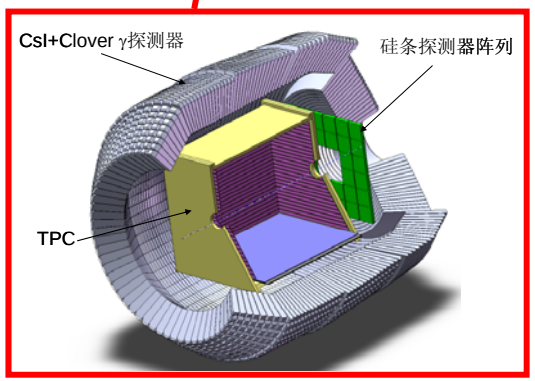


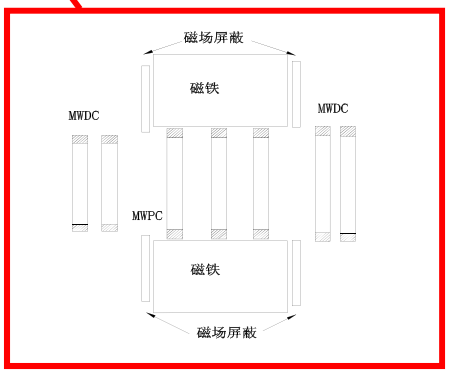
ETF: External Target Facility

Phase II

To be constructed within 3 years







New Detectors

- γ-ball (CsI(Tl) array + Clover)
- TPC (at target region)
- Si-strip array (behind TPC)
- MWPC (inside dipole)

Possible Physics

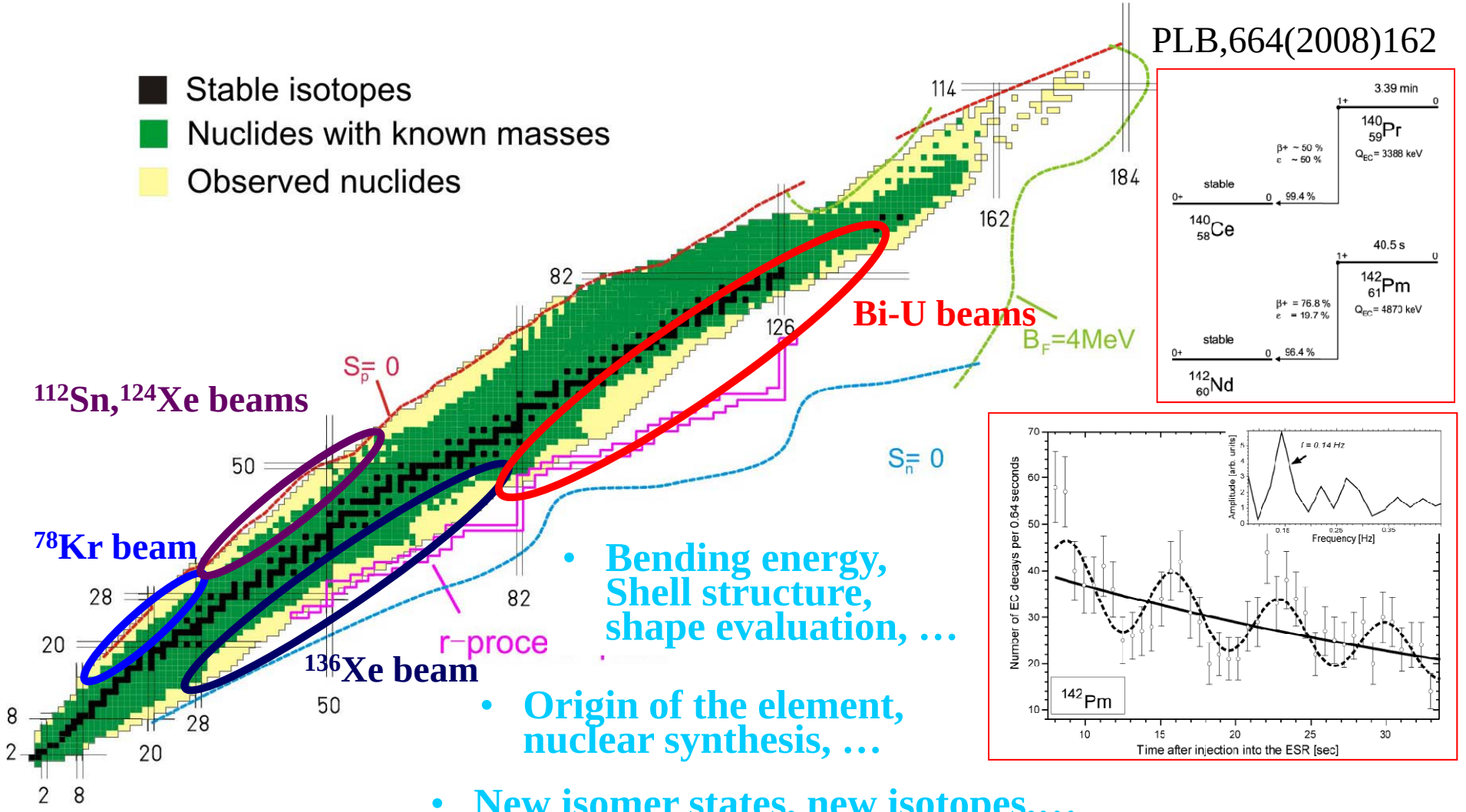
- For RIB Physics
- For EoS of asymmetry nuclear matter

HIRFL-CSR Experiment Next

- **CSRe:**
  - As IMS for mass measurement
  - As SMS for mass & decay measurement
  - Atomic physics at cluster-jet target location
  - Atomic Physics at electron cooler location
- **ETF:**
  - Experiments on weakly bound nuclei
  - EoS of asymmetric nuclear matter
- **Cancer Therapy:**
  - Try different beam delivery modes

Example 1: *Mass & Decay Measurement at CSRe*

PLB,664(2008)162



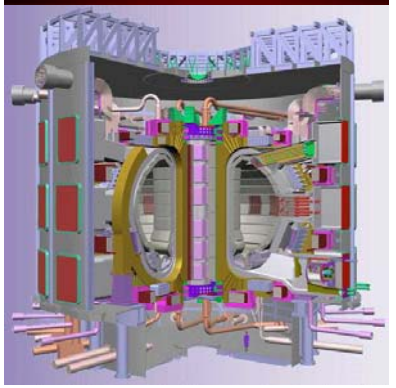
- **Bending energy, Shell structure, shape evaluation, …**
- **Origin of the element, nuclear synthesis, …**
- **New isomer states, new isotopes,…**

2010: try to run CSRe as SMS

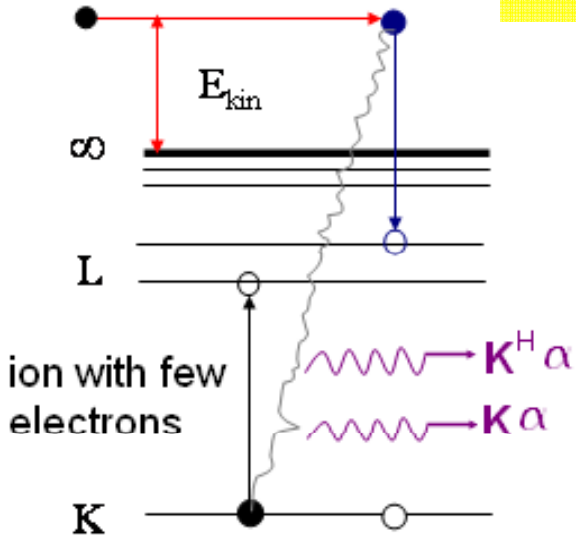
Example 2: *Dielectronic Experiment at CSR*

Aim to study:

- Cross sections and rate coefficients
- DR for highly charged ions to reveal the dynamical aspects of atomic process
- Hyperfine structure of atomic structure to extract the information on charge radii of nuclei

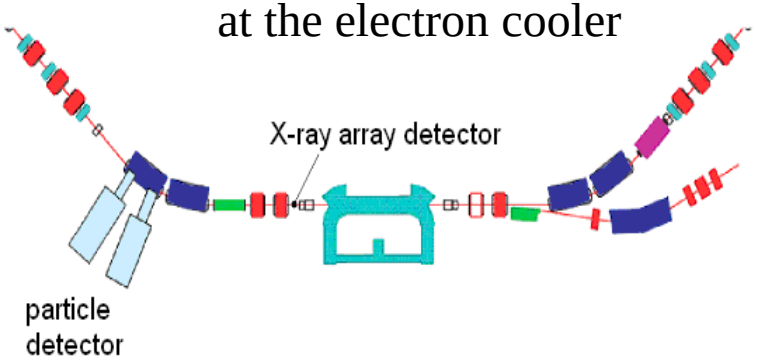


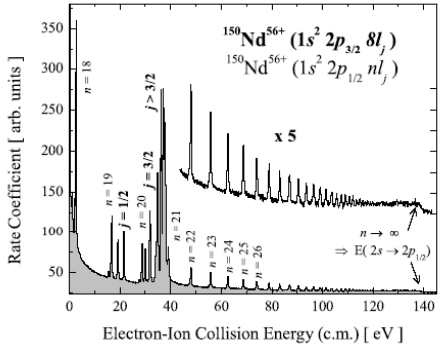
DR-process



$$A^{q+}_{(nl)} + e^- \rightarrow A^{(q-1)+*}_{(n1l1,n2l2)} \rightarrow \begin{cases} A^{q+}_{(nl)} + e^- \\ A^{(q-1)+}_{(m,j)} + h\nu_1 + h\nu_2 \end{cases}$$

Experimental setup
at the electron cooler





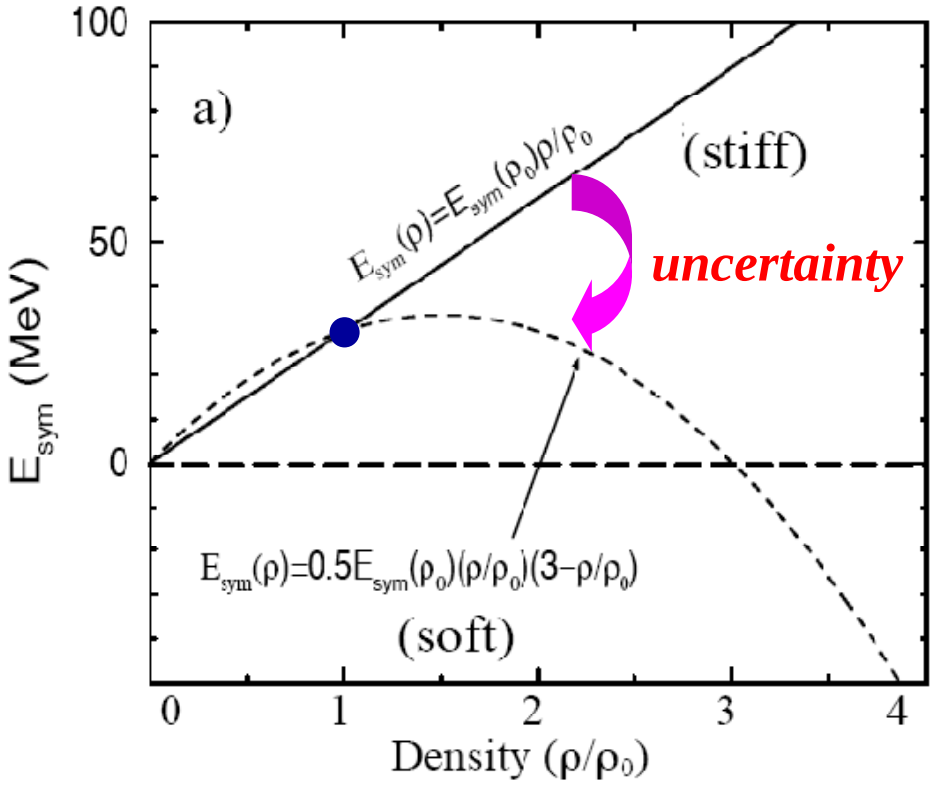
DR EXP at ESR, Brandau

Example 3: *EoS of Asymmetric Nuclear Matter*

$$E(\rho_n,\rho_p) = E_0(\rho_n=\rho_p) + E_{sym}(\rho)\left(\frac{\rho_n-\rho_p}{\rho}\right)^2 + o(\delta^4)$$

symmetry energy

B.A. Li, *Nucl. Phys.* **A708**, 365 (2002)

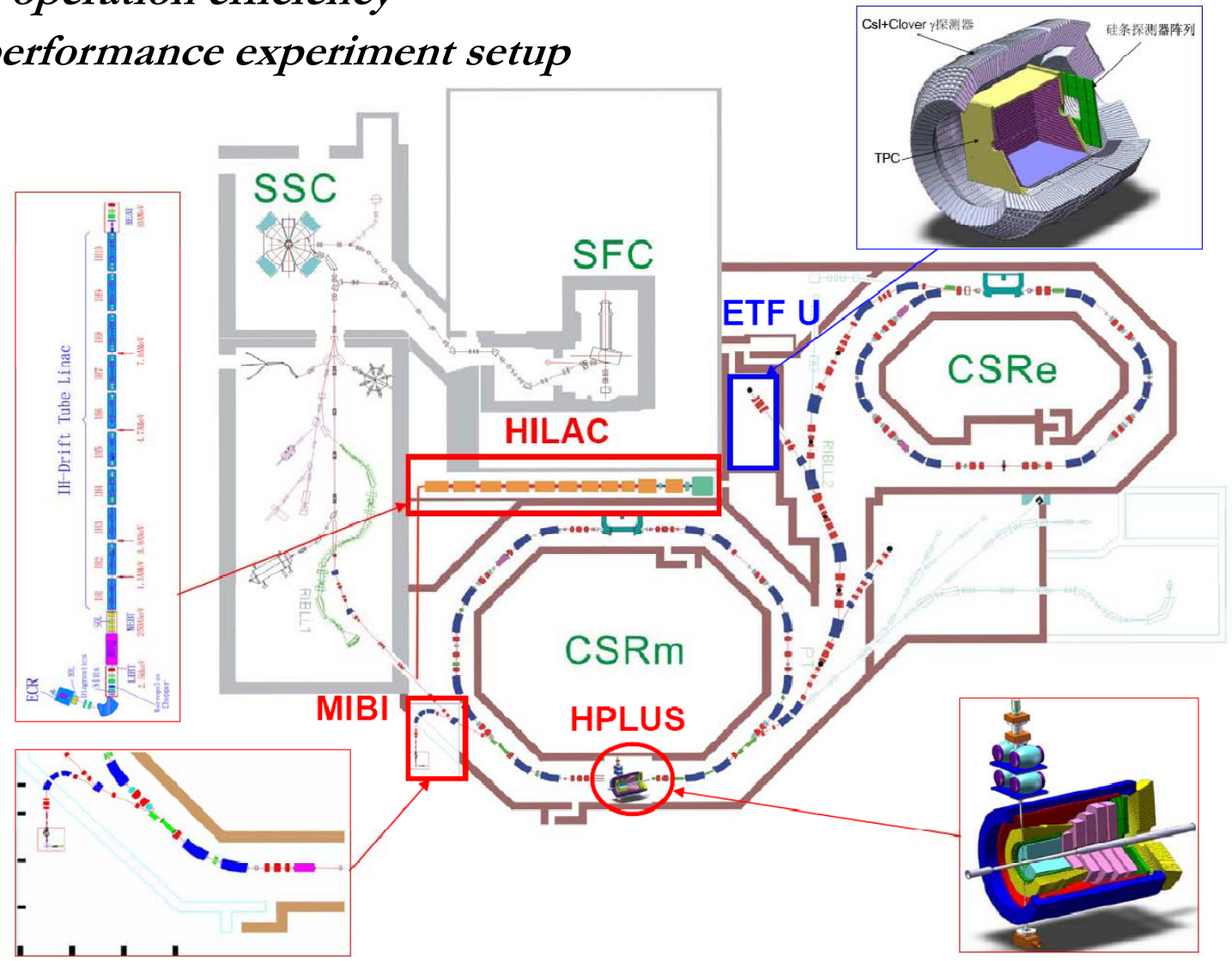


ρ/ρ_0 : 2~3 at CSR

- **n/p ratios, π^+/π^- ratios**
- **Nucleon differential flow**
- **Hard photons**
- **IMFs: isospin transport / diffusion / isoscaling**

HIRFL-CSR Upgrade *(Planning)*

- *System operation efficiency*
- *High performance experiment setup*



Introduction of Nuclear Physics and Technology at Peking University

Yanlin Ye

State Key Lab. Of Nucl. Phys. & Tech.

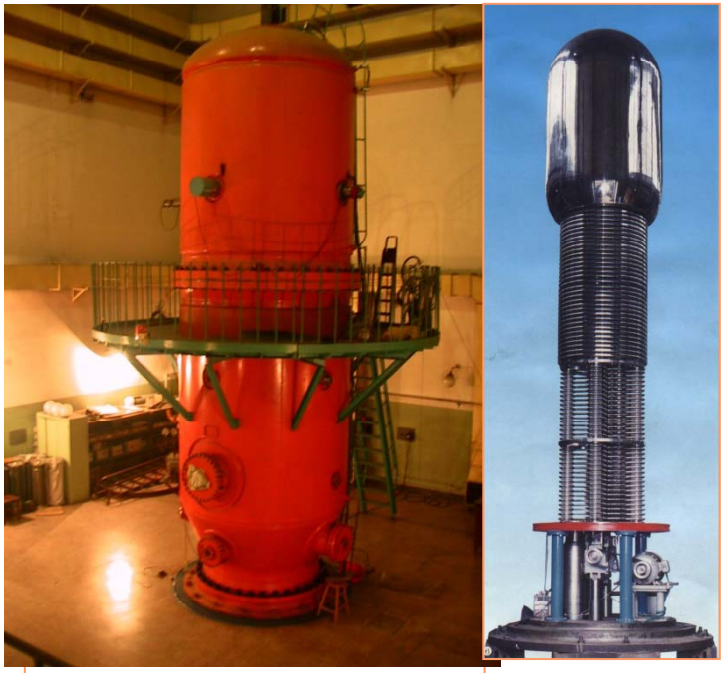
School of Physics, Peking University

2010.01.18

Organizations

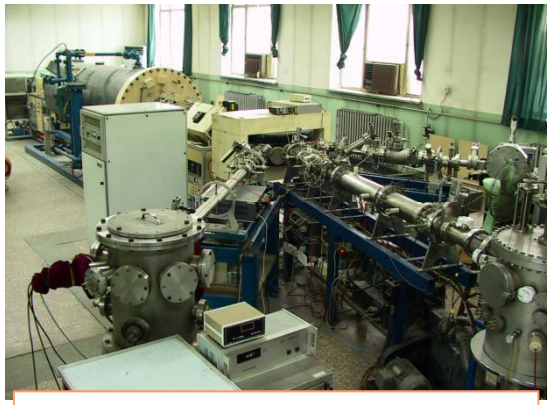
- Department of Technical Physics
- Institute of Theoretical Physics
- Institute of Heavy Ion Physics

  Forming a State Key Laboratory of Nuclear Physics and Technology (since 2007)



4.5MV static

2x6MV tandem



2x1.7MV tandem

a new AMS

RF supercontacting accelerator Lab.

2×3.5cell

一只为大晶粒铌材

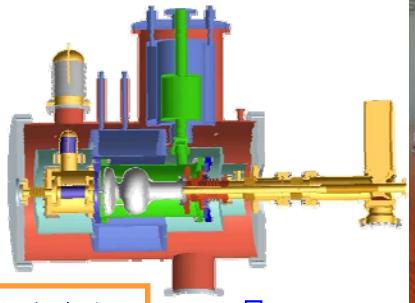
2009

2×9cell其中一只为大晶粒铌材

2008

2007

2006



973计划立项

2005

大晶粒铌材超导腔

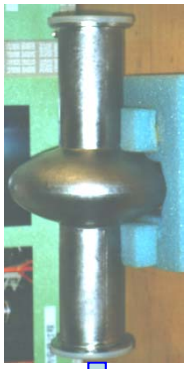
2004

2003

2002

2000

1994



北京大学射频超导课题组成立

1988

RF supercontacting accelerator Lab.

2K液氦
系统

Particle detection Lab.

CMS bulletin April 2006

The Compact Muon Solenoid Experiment

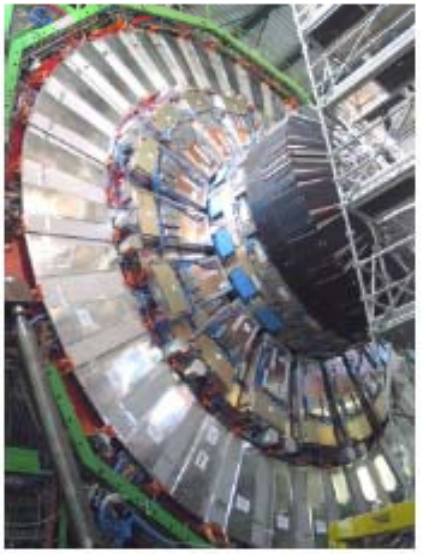
CMS Bulletin

CERN, CH-1211 GENEVA 23, Switzerland

Bulletins are available on CMS internal information server: http://cmsdoc.cern.ch/cms.html

Number 06-01
13 March 2006

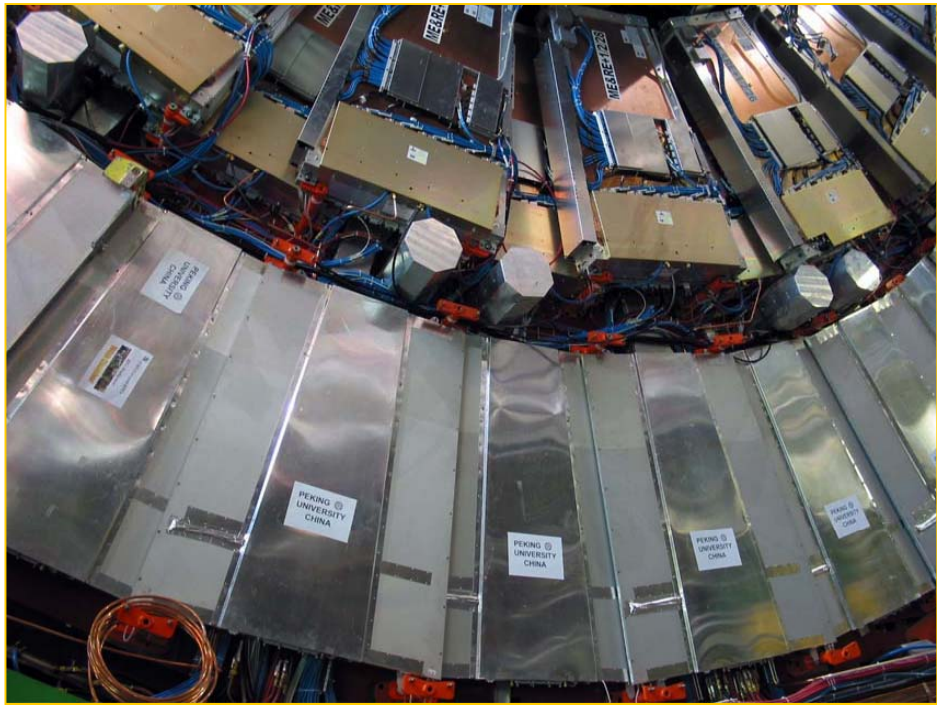
Moving Forward !



YE+1 yoke equipped with CSC/RPC packages (inner ring) and RE1/3 RPC's (outer ring).

The ME1/3 CSC's now cover the RPC outer ring and hence complete the first Muon station on YE+1.

Feb. 2006, PKU-RPC installed on CMS



Nucl. Phys. education base

Nishina School

Thanks for your attention!